Non-radial Solar wind flows and Geomagnetic activity changes during 1973-2003

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Abstract. We have found an association between geomagnetic activity changes and non-radial solar wind flows during the period 1973-2003. The solar wind flow latitude in the GSE system is observed to be higher during intense geomagnetic storm periods. Northward-directed solar wind flows are observed to be higher and a correlation is obtained between this parameter and geomagnetic Ap index during the declining phases of the sunspot cycles. These results suggest an association of non-radial flows from coronal holes and geomagnetic activity during the declining phase of sunspot cycle.

Index Terms. Coronal hole, Corotation Interaction Region, Geomagnetic activity, Interplanetary Magnetic Field.

1. Introduction

It is well-known that geomagnetic activity is controlled by the solar wind. The intensity of geomagnetic storms is proportional to the interplanetary dawn-dusk electric field which is proportional to the product of solar wind speed and southward component of Interplanetary Magnetic Field (IMF) in the GSM system (Tsurutani and Gonzalez, 1997; Gonzalez et al., 1994). The duskward electric field is generally associated with observed negative Dst peak during storm.

Earlier studies on solar wind-geomagnetc activity relations considered only the bulk plasma properties like solar wind speed and IMF characteristics. In this paper, we analyzed the solar wind flow directions with respect to the ecliptic plane which is likely to influence the geomagnetic activity variations. We used relevant solar-terrestrial observations to demonstrate this effect for the period 1973-2003.

2. Data used

The data used in this study is hourly averages of solar wind plasma parameters and Interplanetary Magnetic Field components taken from OMNI dataset compiled by National Space Science Data Center (NSSDC) for the period 1973-2003 (http://nssdc.gsfc.nasa.gov/space/omniweb/). The data includes Dst index, solar wind speed, the north-south component of IMF in the GSM system and latitudinal angle of solar wind flow in GSE system. Ap index values are taken from the National Geophysical Data Center at www. ngdc.noaa.gov.

3. Solar cycle changes of non-radial flows of solar wind near 1 AU

Solar wind is the plasma which is flowing radially outwards and it carries the solar magnetic field which is called the Interplanetary Magnetic Field. Occasionally we observe deviations in solar wind flow associated with various solar coronal phenomena such as Coronal Mass Ejections (Owens and Cargill, 2004).

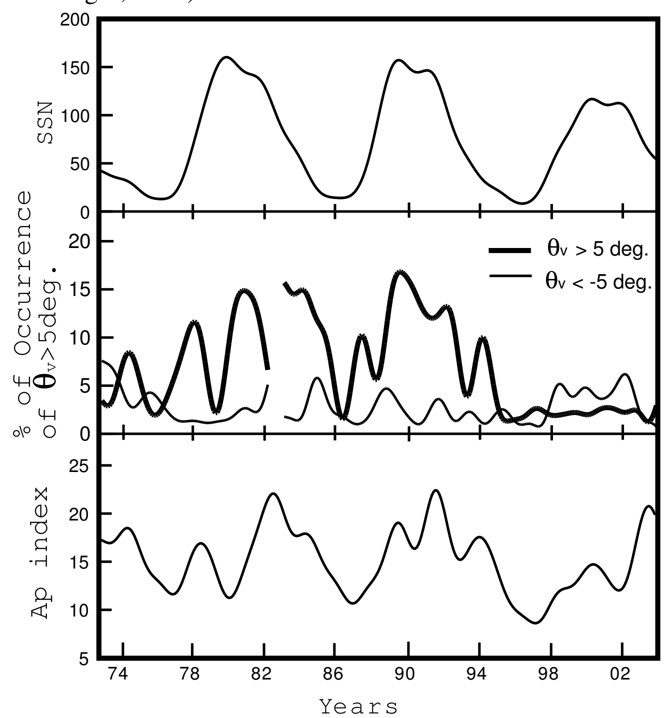

Fig. 1. *Top*: Monthly average sunspot number *Middle*: Monthly percentage of occurrence of solar wind flow latitude (θ_v) greater than +5 degrees (thick line) and less than -5 degrees (thin line) *Bottom*: Monthly Ap index for the period 1973-2003.

For the study of non-radial flows of solar wind, we have taken the solar wind flow latitudinal angles (θ_v) in the GSE system. We have considered only those values of θ_v whose magnitudes are greater than 5 degrees, as non-radial flows. The monthly frequency of occurrence of solar wind flow latitude greater than 5 degrees and less than -5 degrees are calculated separately for the period 1973-2003. The variation of percentage of occurrence of $\theta_v>5^0$ and $\theta_v<-5^0$ is shown in Fig.1b. The monthly average values of sunspot numbers are plotted in Fig.1a and the monthly average Ap index are plotted in Fig.1c. It is observed that the percentage of occurrence is less for $\theta_v<-5^0$ compared to that for $\theta_v>+5^0$. Correlation coefficients are calculated between Ap index and percentage of occurrence of $\theta_v>+5^0$ separately for two different phases (Descending and Maximum) of sunspot cycles 20, 21, and 22. The values are given in Table 1. We can find reasonably good correlation between these parameters during the declining phase of different sunspot cycles studied. No correlation is observed during sunspot maximum phases.

Table 1. Correlation coefficient of percentage of occurrence of solar wind flow latitudes greater than 5 degrees and Ap index for the declining and maximum phases of different sunspot cycles.

Period	Phase of sunspot cycle	Correlation coefficient
1973-76	Declining phase of cycle 20	0.66
1983-86	Declining phase of cycle 21	0.96
1993-96	Declining phase of cycle 22	0.86
1978-81	Maximum phase of cycle 21	0.00
1989-92	Maximum phase of cycle 22	-0.01
1999-2002	Maximum phase of cycle 23	0.06

4. Solar wind flow characteristics during selected geomagnetic storms

Two typical corotating storms are selected in the declining phase of sunspot cycles; one in cycle 20 and another in cycle 22. The hourly values of Dst index, solar wind flow speed V, Bz(GSM), solar wind flow latitude (θ_v) and VBs for 120 hours from 5th July to 9th July 1974 are plotted in Fig.2. The values of |VBs| are calculated only for Bz(GSM)<0 and zero otherwise. It is observed that θ_v is positive just before Dst reaches its peak minimum. θ_v has risen up to 9.3 degrees and the occurrence of positive θ_v values lasted for several hours.

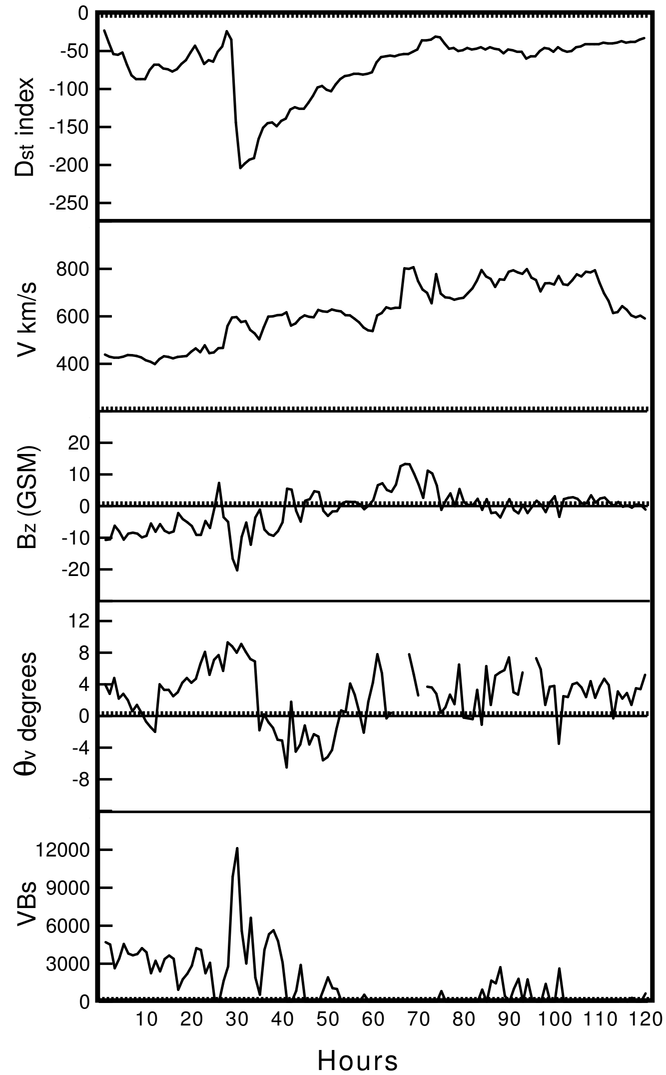

Fig. 2. Solar wind parameters associated with geomagnetic storm during 5-9 July 1974. Top panel of figure shows the plot of Dst index. Solar wind speed, IMF Bz(GSM), solar wind flow latitudinal angle (GSE) and VBs are plotted from the second panel to the bottom.

Fig. 3 represents the storm in October 1996. 120 hours are selected from 22nd - 26th October 1996.Here the maximum θ_v value reached up to 5.5 degrees and positive θ_v values lasted for several hours. These observations show an association between the positive peak in θ_v and the negative peak in Dst index.

5. Discussions

The occurrence of northward-directed non-radial solar wind flows show solar cycle variations with peaks observed in the declining phases of the sunspot cycles. This is observed in cycles 20, 21 and 22 (Fig.1). However, occurrence of southward directed non-radial flows does not show any cyclical variation. Moreover, southward directed non-radial flows occur less frequently. A long-term persistence of the preferred orientation of non-radial solar wind flow with respect to the ecliptic plane is observed for the period 1973-1996.

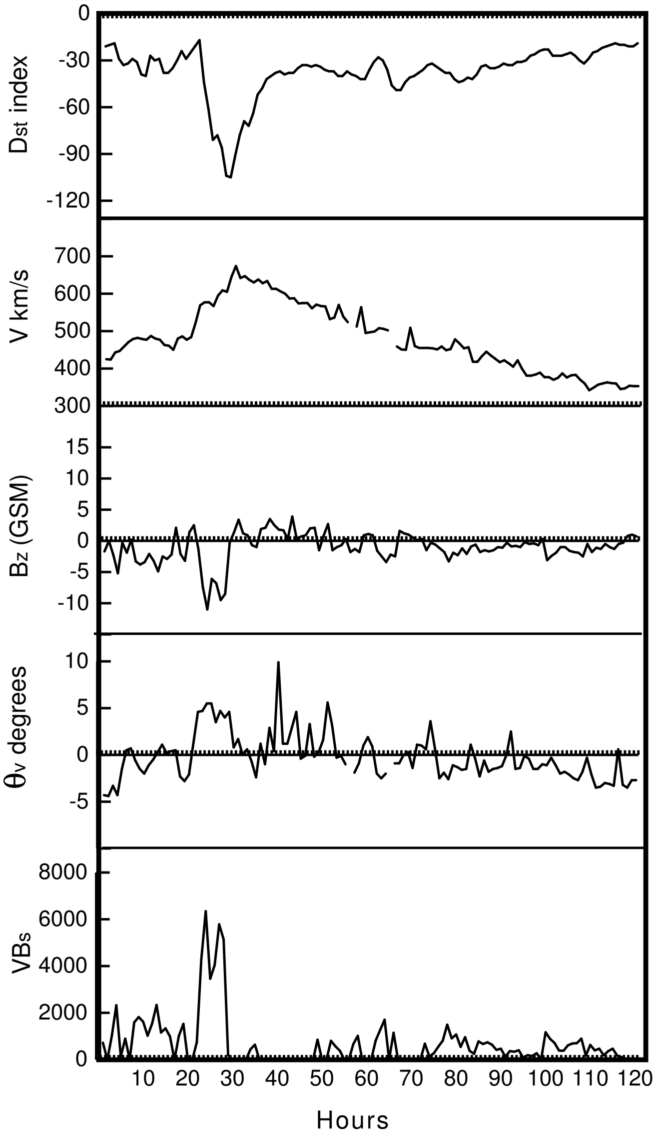

Fig. 3. Solar wind parameters associated with geomagnetic storm during 22-26 October 1996. Top panel of figure shows the plot of Dst index. Solar wind speed, IMF Bz(GSM), solar wind flow latitudinal angle (GSE) and VBs are plotted from the second panel to the bottom.

An association between the non-radial solar wind flow direction and geomagnetic activity is observed during the declining phase of the sunspot cycles. During this period, corotating high speed streams from coronal holes influence the geomagnetic activity. Alfvenic fluctuations in coronal flows can be the cause of the observed large magnitude non-radial flows.

The association of non-radial solar wind flows and geomagnetic activity has been analyzed during selected periods in the declining phase of sunspot cycles 20 and 22. During even cycles, coronal hole activity is more predominant compared to odd cycles.

6. Conclusions

1. From a study of solar wind flow directions observed by earth-orbiting satellites during the period 1973-2003, we have observed a sunspot cycle-dependent change in the occurrence of northward-directed solar wind flows of large amplitude (θ_v>5 degrees) with peaks observed in the declining phase of solar cycles.
2. Correlated changes were observed between geomagnetic Ap index and occurrence of northward-directed solar wind flow angles during the declining phases of sunspot cycles 20, 21 and 22.

The above results suggest that the solar wind flow direction with respect to the ecliptic can influence the magnetic storms observed in earth. Also, the solar wind flow direction has an association with corotating solar wind streams from coronal holes.

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References

Cane, H. V., I. G. Richardson, O. C. St. Cyr, Coronal mass ejection, interplanetary ejecta and geomagnetic storms, *Geophys. Res. Lett*., 27, 2000, p.3591.

Gonzalez, W. D., J. A. Joselyn, Y. Kamide, H. W. Kroehl. G. Rostoker, B. T. Tsurutani, and V. M. Vasyliunas, What is a geomagnetic storm*?, J. Geophys. Res*., 99, 1994,pp. 5771-5792.

Gopalswamy, N., Coronal Mass Ejections of solar cycle 23, J. Astrophys. Astr., (in press), 2005.

Owens and Cargill, Non-radial solar wind flows induced by the motion of Interplanetary Coronal Mass Ejections, *Ann. Geophys*., 22, 2004, pp.4397-4406.

Tsurutani, B. T., and W. D. Gonzalez, The interplanetary causes of magnetic storms, in Magnetic Storms, *Geophys. Monogr*., 98, edited by B. T. Tsurutani, W. D. Gonzalez, Y. Kamide and J. K. Arballo, American Geophysical Union, Washington, D. C., 1997, p. 77.